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A PROPOSAL FOR A UNILATERAL TARGET STATION NUMBER I

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This note describes one side of a target station, designed to offer a rather complete set of beams that can be generated by the extracted proton beam on a nuclear target. In calculating yields we have used the program of Hagedorn and Ranft for 200-BeV protons on protons. The main feature that has emerged generally in designing this station is that it is an exercise in compressing as many beams as possible at the smallest angles to the incident beam. We have taken the boundary condition that we should use only one side of the beam; this leaves open the question of the other side perhaps for a muon beam, neutrino beam, high-energy separated beam or even a mirror image of what we describe.

The second feature that emerges is that the production angles are so small that they are no help in separating the beams, so that experiments may have a finite area in which to set up. The order of beam-transport elements may seem a little odd compared to these that we are accustomed. In this design there are three charged-particle beams, two neutral beams, and they are drawn in Figs. 2(a-e) sequentially as they pass through the experimental area. We shall discuss the beams in turn as they increase in production angle.

The 2.5-mrad Charged Beam (A)

This beam has been designed by Read and Garren as a small-angle beam capable of transporting up to 200 GeV/c and with a momentum bite variable from ±0.1% to ±0.5%. The lower limit is uncertain in the sense that aberrations have not been taken into account in the design but the dispersion at the first focus 0.5 in. for $\Delta p/p$ of 1% together with the small emittance lead one to expect a momentum resolution near this value. The input emittance, due to the finite size of the quadrupole, is 0.1 cm-mrad or better. Upstream of the beam-transport elements is the steel vacuum box, described by Al Maschke, which is under vacuum and contains the external target and beam stop. The beam-transport elements are outside so that we can see whether this simplifying feature yields beams of sufficiently high intensity. We shall see that it does. The quadrupoles have a 2-in. diameter, the bending magnets 1-in. vertical aperture, the horizontal aperture of 2 in. is almost certainly adequate, although this depends on the length chosen for standard magnets. The design fields are shown in Table I together with the beam specifications for a momentum of 150 GeV/c. This beam will probably go to the full energy of 200 GeV/c; the magnification is unity with a focus 75 ft from the last transport element. In Fig. 1 there is a small modification of a drift space between the first set of bending magnets; we shall come to this later. The yields of particles for this beam are drawn in Fig. 2; they assume 3×10^{12} interacting protons/sec, so the numbers can be thought of as a conservative upper limit to the intensities.

Table I. Specifications of Beam A, at 150 GeV/c

Element	Length	Field kG/in. for quadrupoles kG for bends	Distance from UBL
Drift	75 ft		
Quad F	5	8.2	
Drift	7.5		
Quad D	5		
Drift	7.5		
Quad D	5	-7.5	
Drift	7.5		
Quad D	5	-7.5	
Drift	7.5		
Quad F	5	8.2	
Drift	25		
Bend	25	10	
Bend	25	10	0.5 ft
Bend	25	10	
Bend	25	10	
Drift	25		
Quad F	5	8.2	
Drift	7.5		
Quad D	5	-7.5	
Drift	7.5		
Quad D	5	-7.5	
Drift	7.5		
Quad F	5	8.2	
Drift	25		
Bend	25	10	
Bend	25	10	13.8 ft
Bend	25	10	
Bend	25	10	
Drift	25		
Quad F	5	8.2	
Drift	7.5		
Quad D	5	-7.5	
Drift	7.5		
Quad D	5	-7.5	
Drift	7.5		
Quad F	5	8.2	
Drift	75		36 ft

Solid angle of beam ~ 2.0 μster

Dispersion at focus 0.5 in. for 1% $\Delta p/p$

This beam can also be used to make a diffraction-scattered proton beam at the EPB energy. The momentum transfer at 2.5 mrad at 200-GeV/c protons is about 100 $(\mathrm{MeV/c})^2$. This leads to a diffraction-scattered flux of approximately 10^{-3} of the main beam. Since it is possible to alter this production angle slightly by moving the EPB, then even higher fluxes can be obtained by coulomb scattering. The limit on the flux is almost certainly not the particles available but the background radiation problem, for in the limit the EPB could be transported down the beam line.

The Neutral Beams

These beams were designed to go down the transport elements of the 2.5-mrad and 5-mrad charged beams. The first bending magnet of the charged beam has the return leg towards the undeflected proton-beam line (UBL) with the second magnet after the drift space with the return leg the other way. The difference in angle of the charged beam and neutral beam in the drift space is 16 mrad to the UBL. So with 25 ft of drift, the lateral displacement is 4.8 in. This is sufficient to separate the charged and neutral beams allowing the 2.5-mrad neutral beam unimpeded progress toward the neutral-beam area. A more difficult problem is the 5-mrad neutral beam which begins in similar fashion to traverse the 5-mrad charged-beam transport. However, it also will cross this space, for at the beginning of AB1 it is displaced $2.5 \times 10^{-3} \times 180$ ft = 5 in., which allows it to clear the windings; the drift space should be enough to allow this beam also to cross the charged 2.5-mrad beam. A similar problem exists between BB1 and BB2; it too is soluble. Romanowski has estimated the shape of the spectrum in the 2.5-mrad neutral beam. It is shown in Fig. 3. The calculation is justified in his report on neutral-beam experiments in this study. The yield of neutrons is $2 \times 10^{+9}$/burst of 3×10^{12} interacting protons. In this beam we also have 10^{8}/burst K_L^o and 2×10^{5}/burst K_S^o at 250 ft. The solid angle is 10^{-7} sterad limited by the aperture of the bending magnet in the charged-beam transport. The 5-mrad beam has an improved K/n ratio; this is treated by Smith, also in this study, in the section on neutral beams (B. 4).

<u>The 5-mrad Charged Beam (B)</u>

This beam was designed by J. Lach and is based on the experience with the BNL rf-separated beam. The two cavities operate at X-band, and it is assumed that superconducting cavities will be available to provide a proper-duty cycle. It is not a finished design but is shown as a typical rf-separated beam with momentum resolution from 0.1-0.5% which will separate up to 30 GeV/c. The solid-angle acceptance is 2 μster and the yield expected from 3×10^{12} interacting protons is shown in Fig. 4. The layout is in the first figure. The only features to note are the cavities are 3-m long, deflecting wanted particles by 0.5 mrad. The first bending magnets have their return legs away from UBL, neutral and charged separation is complete between BB1 and BB2.

<u>The 9.5-mrad Beam (C)</u>

The consideration of this beam led simply to estimate the smallest angle that could be obtained in a way compatible with the existence of the other beams that we have described. The angle can be made smaller by placing a "C" magnet halfway down the Maschke box so as to clear the actual beam lines of the other beams and clear the hardware of beams A and B. A reasonably conservative placing gives a limit of 9.5 mrad as the smallest angle. If we estimate the solid angle we might achieve as 1 μster, then the yields are shown in Fig. 5. The details of placement of the steering magnets are shown in Fig. 1.

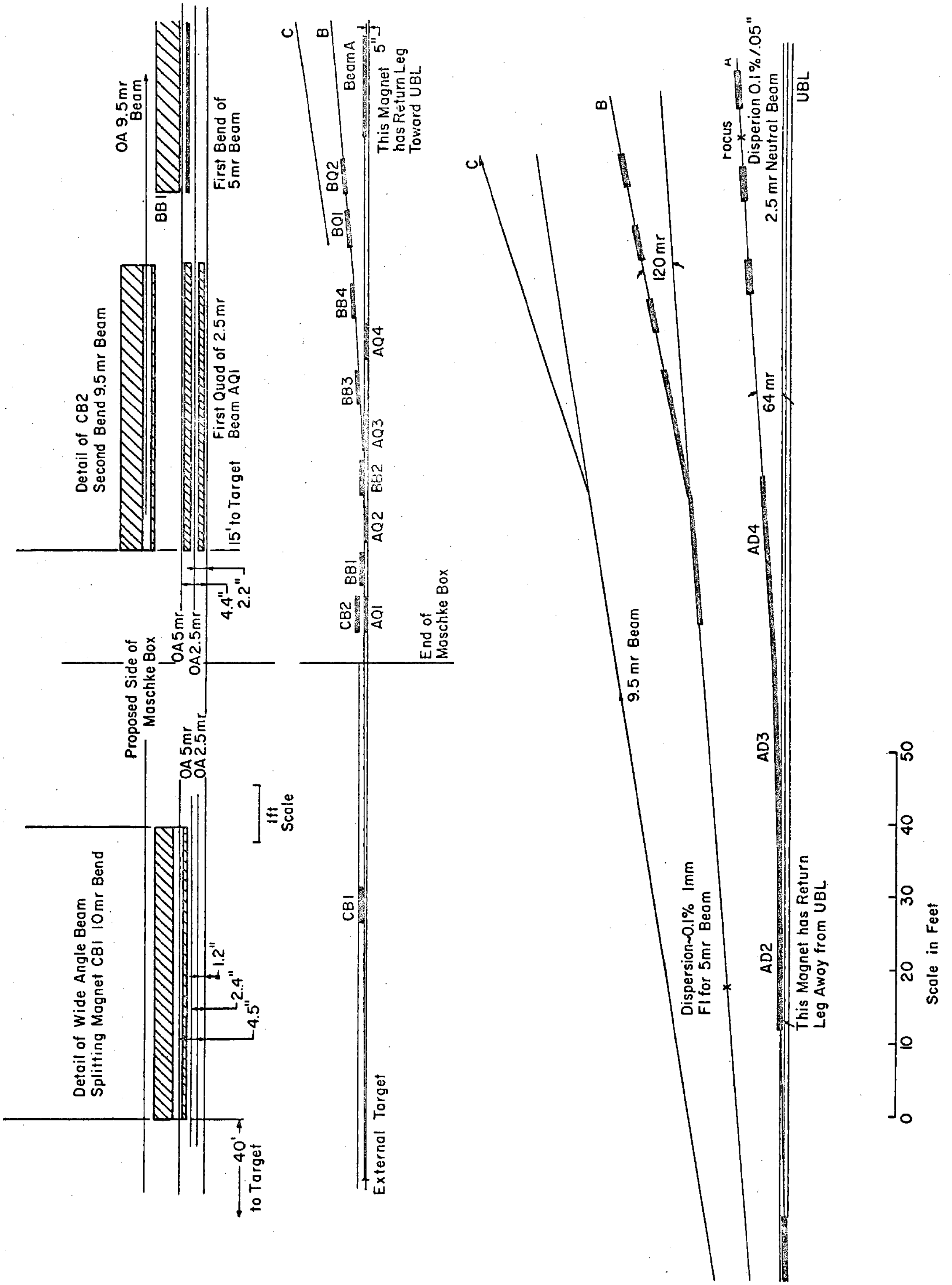


Fig. 1(a-b). The central and upper drawings show the first portion of the target and beam-transport arrangement; at the top some details of the magnets are enlarged. Bending and focusing magnets, labelled B, Q, are prefixed with A, B, C, etc. to denote different beams. (b) The lower drawing shows the second section of the beam layout

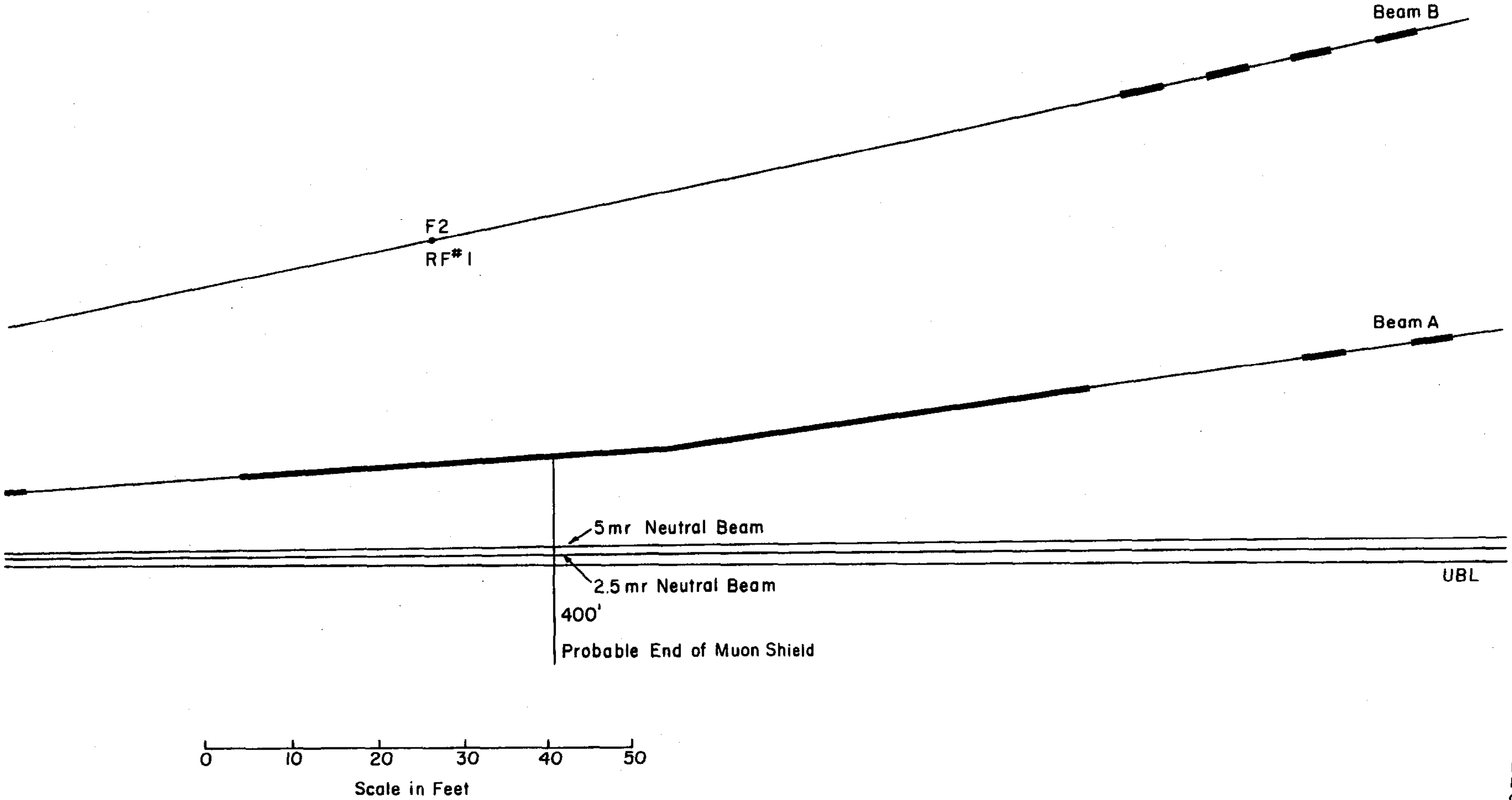


Fig. 1(c). Third section of beam layout.

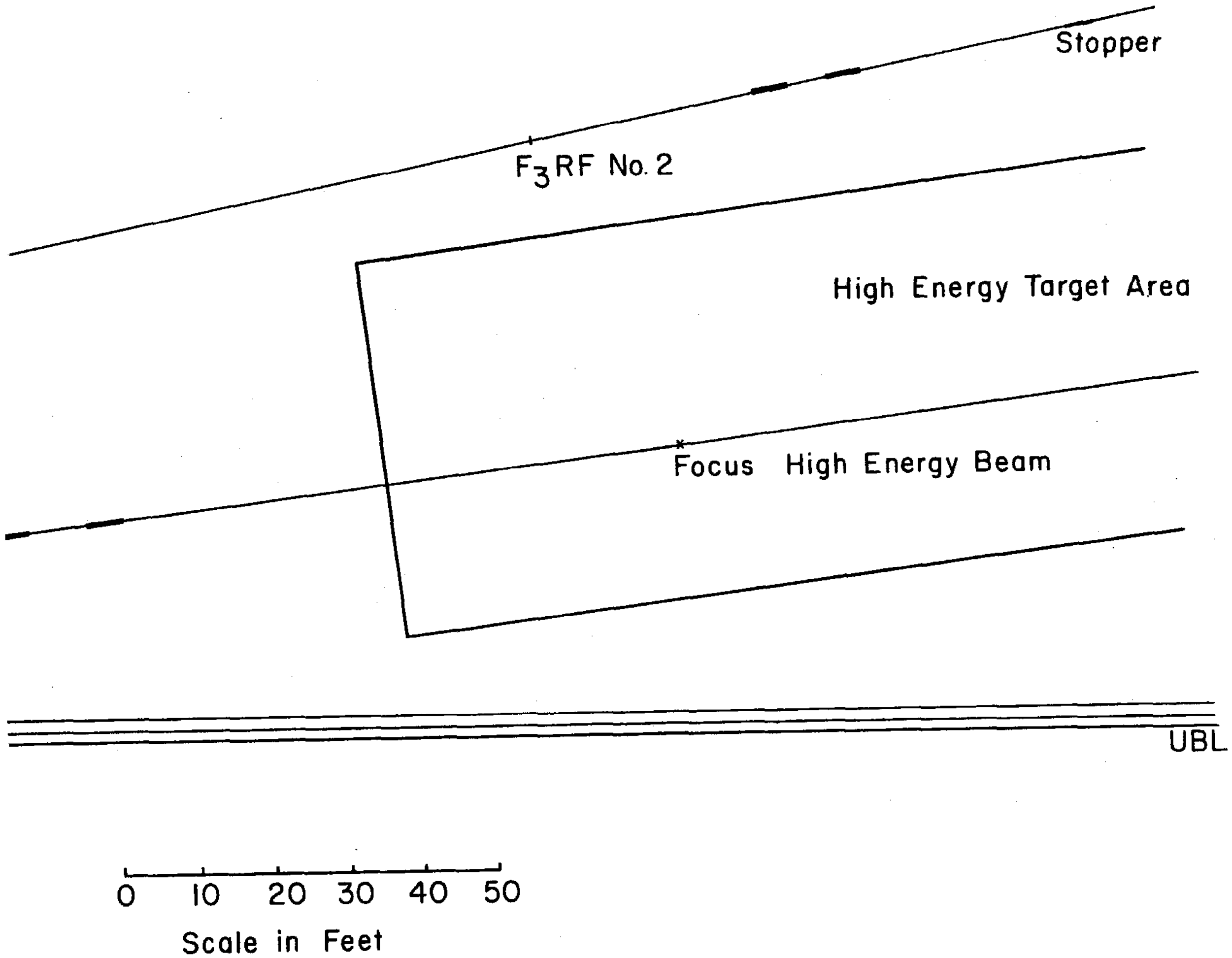


Fig. 1(d). Fourth section of beam layout.

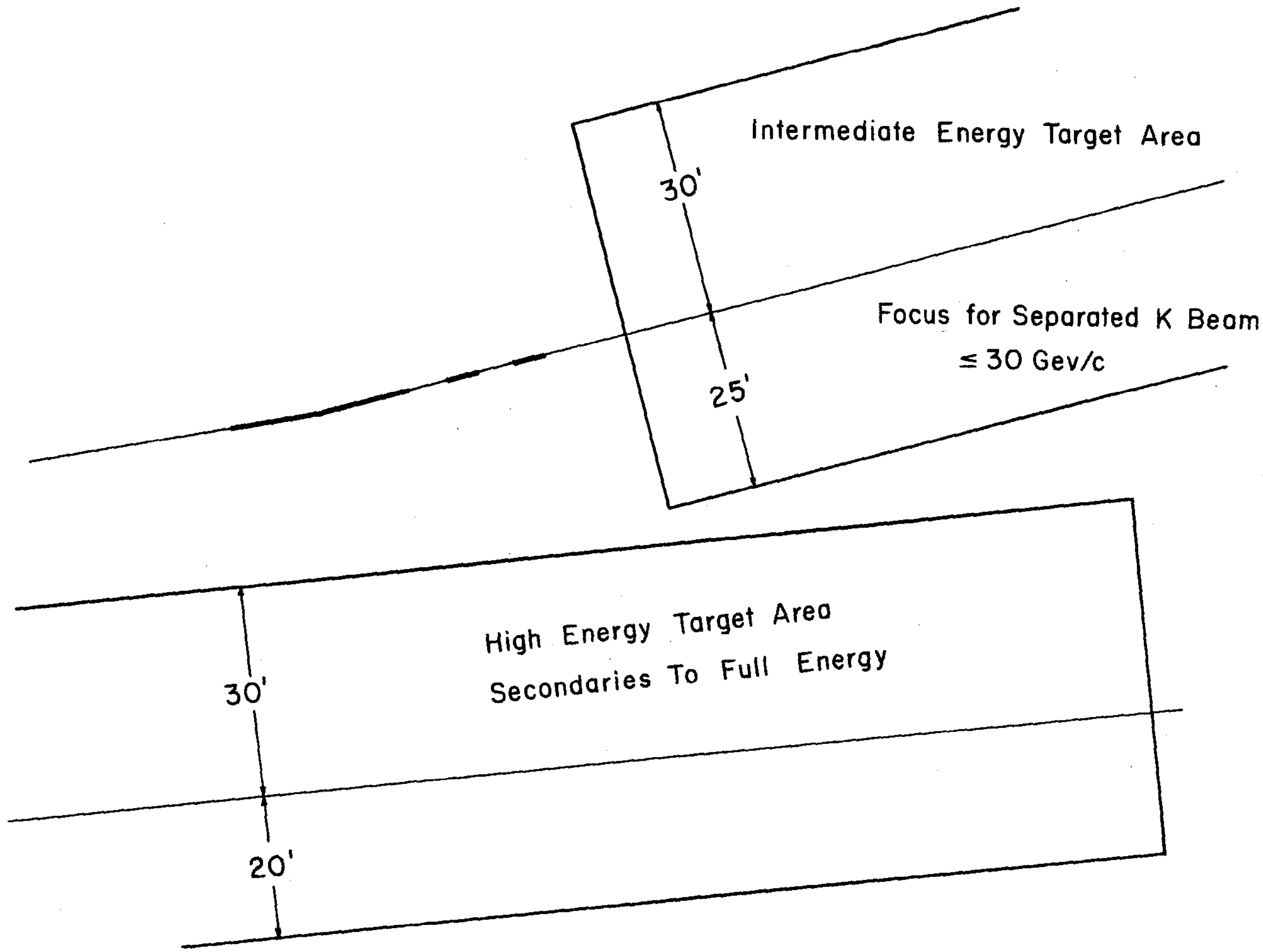


Fig. 1(e). Fifth and last section of beam layout.

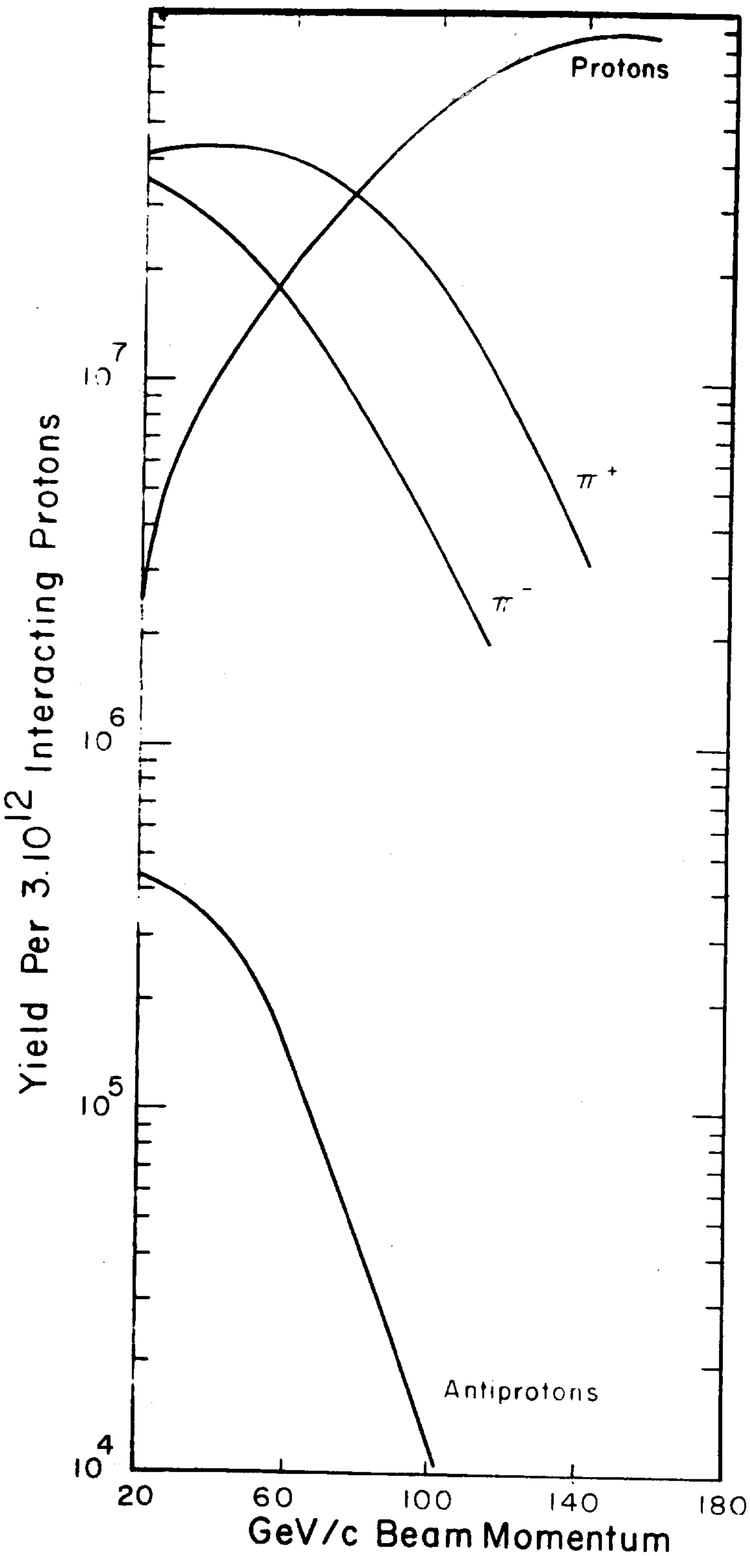


Fig. 2. Particle yield from beam A, assuming momentum spread of 0.1 GeV/c.

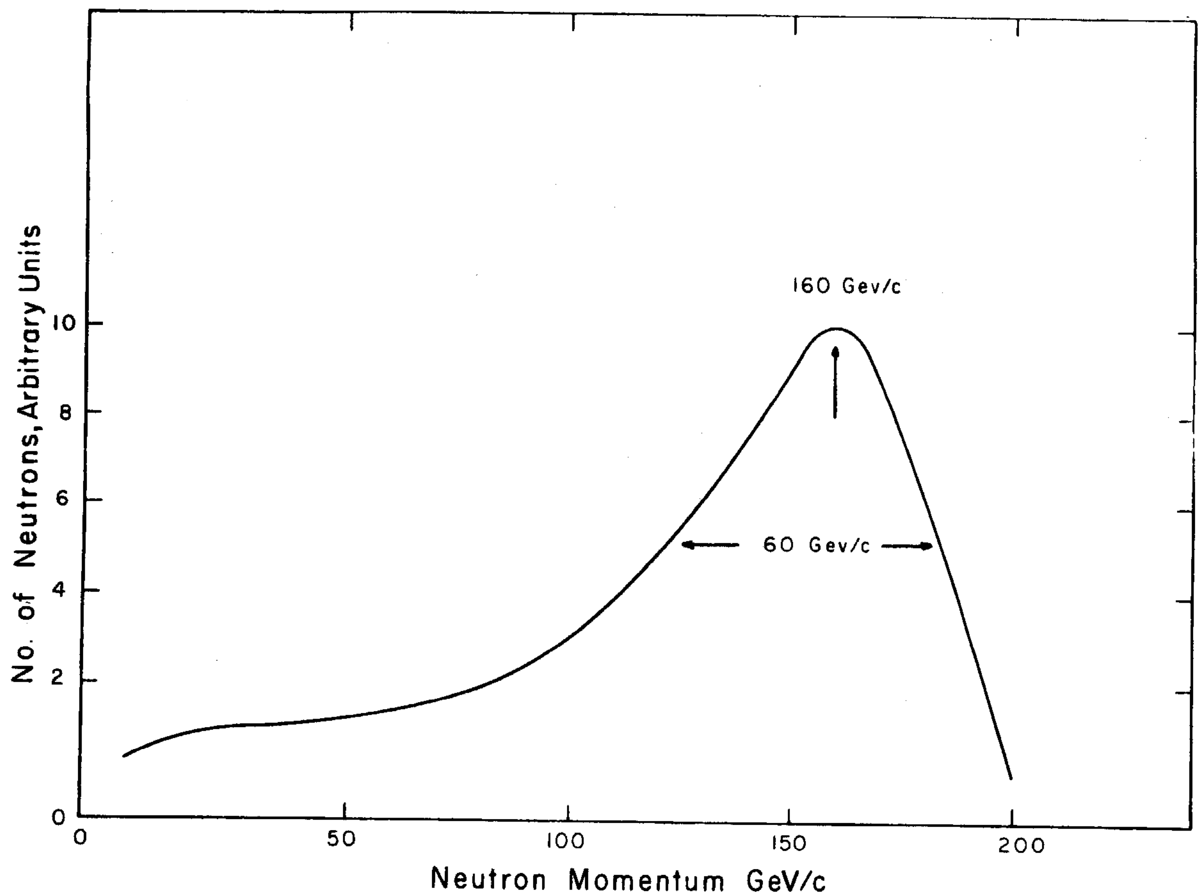
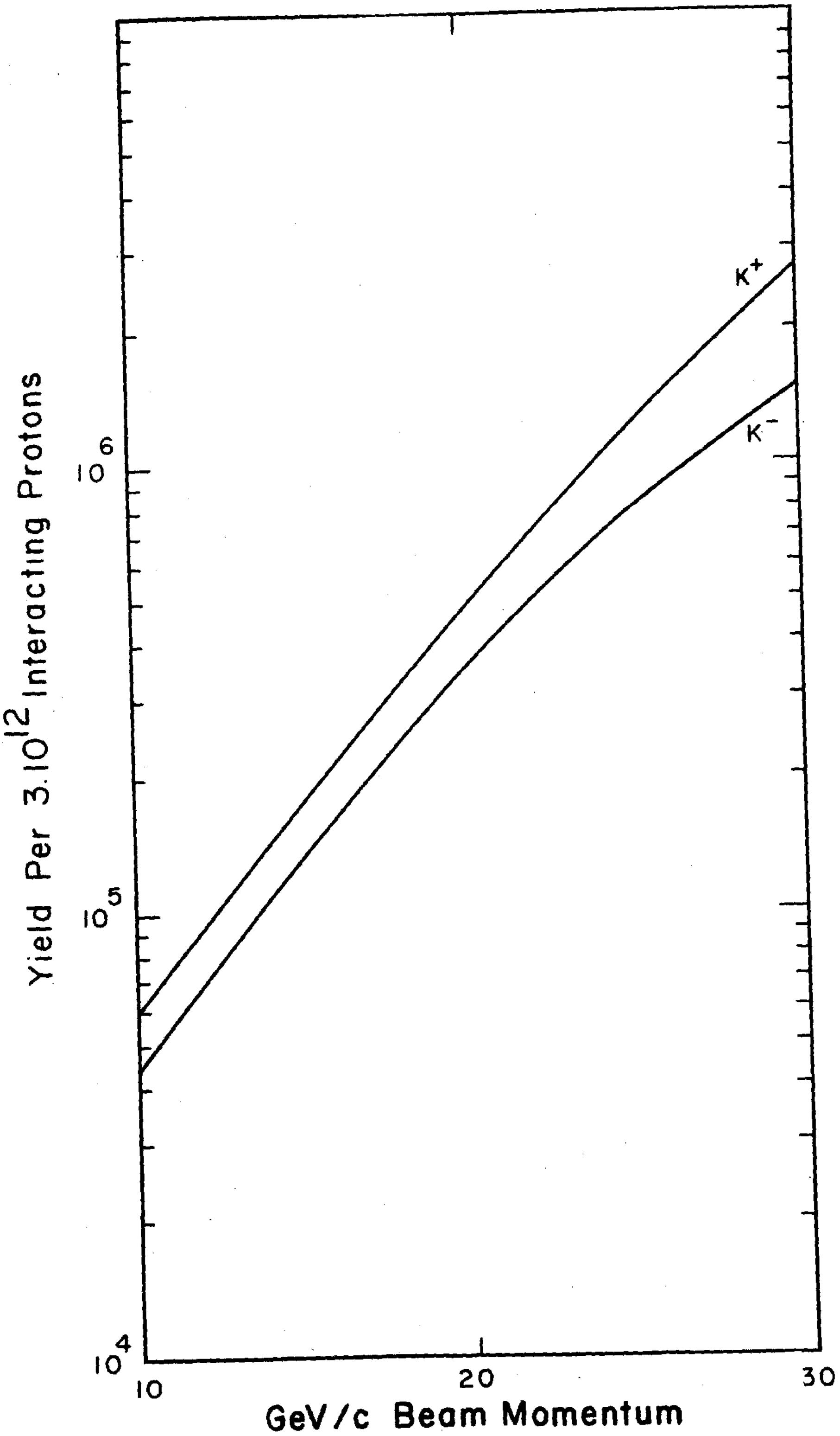


Fig. 3. Spectrum of neutrons produced at 200 GeV, at 2.5 mrad production angle.



g. 4. Particle yield from rf-separated beam B, assuming momentum spread 30 MeV/c.

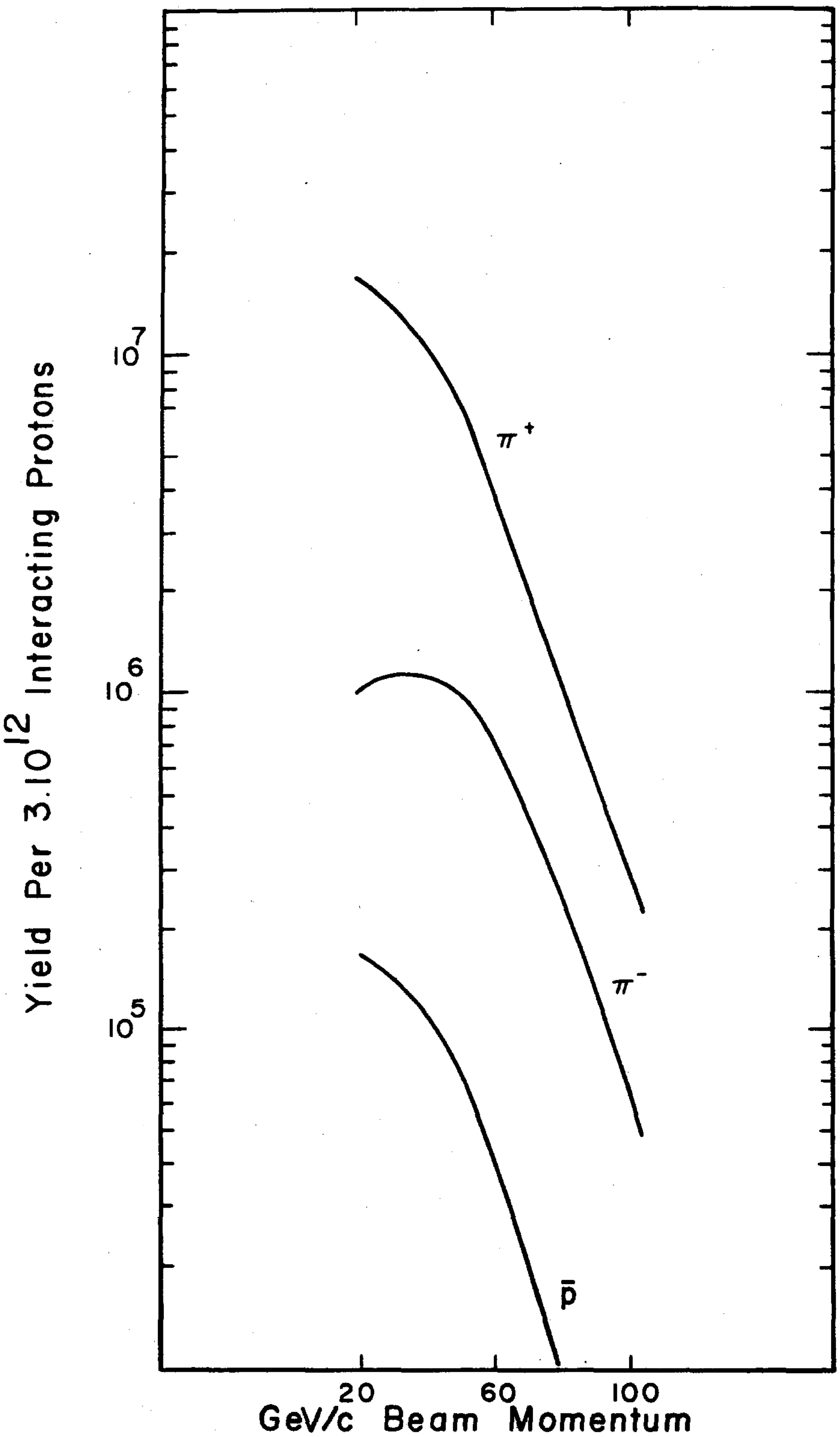


Fig. 5. Particle yield from beam C, assuming a momentum spread of 0.1 GeV/c and a solid angle of 0.9 microsterad.